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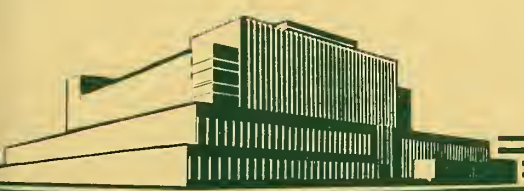

FOREST PRODUCTS LABORATORY
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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

IMPORTANCE OF DRY LUMBER

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The importance and the degree of seasoning required for different wood uses vary widely. This is entirely normal when it is recognized that the functional development of the tree from which the lumber is cut takes place in the presence of moisture, and the wood remains "green" or moist throughout the life of the tree. A southern pine log 16 feet long and 15 inches in diameter with 4 inches of sapwood may weigh as much as 1,250 pounds, about 47 percent of which is water, amounting to about 70 gallons. As another example, a white oak log 16 feet long and 18 inches in diameter with 3 inches of sapwood may weigh as much as 1,850 pounds, of which about 1,050 is water, comprising 126 gallons. Contrary to common belief, the sap of a tree is not up in summer and down in winter, but the moisture content is essentially the same throughout the year. This moisture is present in freshly cut lumber, and for a number of reasons must largely be removed by seasoning to make the lumber suitable for many of its various uses.

Variation of Moisture in the Tree

The amount of moisture in the living tree varies greatly among species, individual trees of the same species, different parts of the same tree, and between heartwood and sapwood.

Many coniferous species have a large proportion of moisture in the sapwood and much less in the heartwood. Most hardwoods, on the other hand, show more nearly the same moisture content in heartwood and sapwood. Extreme limits observed in the moisture content of green wood range from as low as 30 to 40 percent in the heartwood for such species as black locust, white ash,

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[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

Douglas-fir, southern pines, and various cedars to about 200 percent in the sapwood of some coniferous species. In the heartwood of some species the moisture content is high at the base of the tree and becomes less toward the top.

For example, in a number of green redwood trees examined, the heartwood decreased in average moisture content from 160 percent at the stump to 60 percent at heights about 100 feet. In this instance, however, the moisture content of the sapwood increased slightly with height in tree.

Fiber-saturation Point and Moisture Content

Moisture in wood in the green state is in part held by the cell walls and in part within the cell cavities, much in the same manner as water is held in a container. When green lumber is exposed to the air it loses moisture, first from the cell cavities, and then from the cell walls. The condition in which the moisture has been removed from the cell cavities while the cell walls remain saturated is known as the "fiber-saturation point." It varies from 25 to 35 percent moisture content.

The "moisture content," as generally referred to, is the weight of the water contained in the wood, expressed as a percentage of the weight of the ovendry wood. As indicated in some of the examples given, the moisture content of green wood may be over 100 percent, and exceed the weight of the ovendry wood.

Any piece of wood will give off or take on moisture from the surrounding atmosphere until the moisture in the wood has come to a balance with that in the atmosphere. The moisture in the wood at the point of balance is called the equilibrium moisture content.

Assuming constant temperature, the ultimate moisture content that a given piece of wood will attain, expressed as a percentage of the ovendry weight, depends upon the relative humidity of the atmosphere surrounding it, which is the amount of vapor in the air expressed as a percentage of the amount it would hold at saturation. This relationship is illustrated by figure 1 which shows, for example, that wood kept in an atmosphere constantly at 70° F. and 60 percent relative humidity will eventually come to a moisture content of about 11 percent. This is true whether the piece is initially at a higher or lower moisture content than that corresponding to the equilibrium condition.

As the wood dries below the fiber-saturation point, shrinkage as well as further loss in weight takes place.

If a box is made of green lumber, and stored in a dry room, the wood will dry until its moisture content comes into equilibrium with the surrounding atmosphere. The resulting shrinkage causes loss of nailholding power and consequently loss in strength of the box. Tests have shown that such a box, nailed in a green condition, dried in storage 45 days, and tested at 10 percent moisture content, may have only about one-fourth the strength as when made of dry lumber.

Advantages of Seasoning

When the conditions of service are such that the lumber would ultimately attain an equilibrium moisture content corresponding to dry material, it is preferable that the lumber be dried before being put in place or manufactured rather than be allowed to season in place, with accompanying shrinkage.

There are a number of distinct and important advantages in seasoning.

1. Seasoning reduces the likelihood of stain, mildew, or decay developing in transit, storage, or subsequent use. Blue stain fungi and wood-destroying fungi cannot grow in wood with a moisture content of less than 20 percent.

2. The shrinkage that accompanies seasoning is made to take place before the wood is put to use. The importance of this feature varies greatly with the use.

3. Wood increases in most strength properties as it dries below the fiber-saturation point. The increase in strength with seasoning is much greater in small clear specimens of wood than in large timbers containing defects. Due allowance is made for the increase in strength resulting from seasoning in stress graded material 4 inches and less in thickness. In thicker material the increase in strength to a large extent is offset by the influence of defects that develop in seasoning.

4. The strength of joints made with common fasteners, such as nails and screws, is greater in seasoned wood than in green wood seasoned after assembly. Panels made by nailing green lumber to a frame and allowed to season indoors one month before being tested were found to be about one-half as rigid as similar panels made of seasoned lumber and tested immediately. When bolts and connectors are used in green wood lower stresses are required than for dry material. Also, due to shrinkage, bolted joints in green material require retightening after the material seasons. However, it must be remembered that the availability of dry lumber is related to size. Where large size timbers are required, due consideration must be given to the effect

of seasoning and shrinkage unless it has been predetermined that the material is available in a suitably seasoned condition.

5. Glued wood products can be expected to perform better when the moisture content of the wood at the time of gluing is as near as practicable to the average moisture content which the product is expected to have in service, provided it is below some 15 to 18 percent. Moisture changes in glued wood products induce stresses that favor warping and checking. These stresses reduce the strength of the glued joints and should therefore be avoided as far as possible.

6. Seasoning reduces the possible damage from insects that bore holes in wood in either the larval or adult stage. Seasoning protects wood from attack of most of these insects. The Lyctus or powder-post beetles work in dry wood, but exclusively in hardwoods and mostly in the sapwood only. If the dry wood is coated with the usual finishes, this beetle cannot lay its eggs in the wood, preventing pinholing. If the wood becomes infected before fabrication and finishing, losses can be prevented by a heat treatment, treatment with chemicals, or fumigation. Damage from Ambrosia beetles, which bore pinholes in green wood, can be prevented by heat sterilization in kiln drying or by rapid air-drying immediately after the logs have been converted into lumber.

7. Successful treatment of wood with preservatives to extend its use under conditions favorable to decay requires seasoning prior to treatment for best results. Applying surface treatments of preservative oils to green or wet wood is not very effective, because preservatives so applied cannot penetrate wood that is already full of water. In treating timber by pressure processes, however, artificial means of conditioning green timber to make it more absorptive can be used and thus avoid the long delay incident to air-drying. Nevertheless, air drying, despite the greater time, labor, and storage space required, is the most widely used method of conditioning.

8. The electrical resistance of wood changes greatly as it dries. With a change in moisture content from about 30 percent to an ovendry condition, the resistance increases a million fold. Wood used in electrical equipment as an insulator or a dielectric should be kept dry.

9. Dry wood is a better thermal insulating material than wet wood. The thermal conductivity of wood is dependent upon a number of factors of which moisture content is one of the most significant.

10. The appreciable reduction in weight accomplished by seasoning is an important factor in reducing shipping costs by rail.

Problems Associated with Seasoning

In addition to the significant advantages of seasoning, other aspects of seasoning must not be overlooked.

1. Not all species of wood are easy to season. Some dry very slowly, and it is not always possible to meet ideal conditions even when drying facilities are available.

2. Satisfactory drying involves preventing or keeping to a minimum seasoning defects, such as checks and honeycombing. The amount of degrade in seasoning varies with species and size of lumber, and is in general more with the lower than the higher grades. Kiln drying research is aimed at development of drying schedules which will keep drying time, as well as degrade, to a minimum.

3. It is more difficult to season structural timbers than lumber in smaller sizes. The long time required for air drying, the degrade, and the insurance costs involved limit economic practicability. With large timbers, and particularly lower grades, the development of seasoning defects usually offsets any increase in strength with seasoning.

4. Drying adds moderately to the cost of lumber, and dry lumber can be expected to command a higher price proportionally than unseasoned material.

Uses for Green or Partially Seasoned Wood

Green wood has certain obvious uses where seasoning need not be considered, such as uses under water and under ground. Large timbers that would require an excessively long seasoning period if dried prior to use are generally used green and allowed to season in place. Many large members of wood boats are installed essentially green, and have given satisfactory service. Also green or unseasoned timbers are commonly used in heavy rough construction, such as bridges, trestles, and mill constructed buildings. In some such uses, however, some maintenance can be expected where shrinkage is involved, and consideration should be given to the possibility of decay, if untreated, particularly at joints and contact points.

Improved Characteristics of Dry Lumber

Wood is dried chiefly to improve its serviceability and suitability. For most of the purposes for which wood is used, particularly in assembled form,

reduction of the shrinkage produced by seasoning is the most important consideration. In order to maintain its size and form, wood should when possible be dried to the moisture content it is expected to attain in service. Seasonal variations in moisture content due to climatic changes will cause slight changes in dimension and these changes are often retarded by coatings of paint, varnish, or lacquer. The objective then of the seasoning process is to bring wood down to a moisture content in reasonable agreement with the conditions of use, so that the main shrinkage will have taken place in the rough product rather than in the semifinished or finished, assembled product. From then on the seasonal changes in dimension should seldom cause much trouble.

Seasoning Terms

The trade terms "shipping dry," "air-dry," and "kiln-dry," although widely used, have no specific or agreed meaning with respect to quantity of moisture. The wide limitations of these terms, as ordinarily used, are covered in the following statements which, however, are not to be construed as exact definitions.

"Shipping dry" is the term used to designate lumber that is partially air dried to reduce shipping charges, and may have a moisture content of 30 percent or more.

"Air-dry" is the term used to designate lumber that has been exposed to the air for either partial or complete seasoning. If exposed for a sufficient length of time it may have a moisture content range from 6 percent, as in the arid Southwest, to 24 percent, as in the winter in the Pacific Northwest. For the United States as a whole, the minimum moisture content range of thoroughly air-dry lumber is 12 to 15 percent.

"Kiln-dry" is the term used to designate lumber that has been either partially or fully seasoned in a dry kiln. Properly kiln-dried lumber in the upper grades of softwoods and the upper and lower grades of hardwoods intended for general use will ordinarily have a moisture content of 6 to 8 percent. Lower grade kiln-dried softwood lumber is likely to have a moisture content of 15 to 22 percent.

The air-drying of wood consists of piling the lumber outdoors so that the air currents can circulate through the pile and carry away the moisture from the surfaces of the wood. It is a slow process, but on the whole satisfactory. Kiln drying is a process designed to hasten drying by carefully placing lumber in a chamber called a kiln, and circulating large volumes of heated air

through it. Modern dry kilns equipped with blowers or fans can dry lumber more thoroughly in a few days than can be done by air-drying in months. For some kinds of lumber, such as flooring, the relatively low moisture contents required can only be obtained by kiln drying.

Storage and Handling of Dry Lumber

Once lumber has been dried, it is desirable that it be kept dry until fabrication is completed. Air-dried stock may hold its condition well in shed storage, but kiln-dried stock will likely tend to reabsorb moisture. Heated storage sheds for kiln-dried lumber and dimension stock are often found in fabrication plants, and provide ideal storage for lumber kiln-dried down to 6 or 8 percent moisture content.

When dry lumber is delivered to a building site, it should preferably be covered to keep it dry. It is especially desirable that particular attention be given to such items as sash, trim, and flooring.

Optimum Moisture Content for Various Uses

The optimum moisture content for wood for any given use is that at which subsequent changes in moisture content are reduced to a minimum, thereby reducing so far as possible dimensional changes when the wood is put in service. In other words, as previously mentioned, wood should be seasoned to the moisture content it will ultimately come to in service, or as near thereto as possible or practicable.

Wood to be Treated with Preservatives

Poles, posts, and railroad ties, even though used in contact with the ground, are usually air-dried somewhat prior to treatment with wood preservatives. This drying results both in improved absorption of the preservatives, and reduced likelihood of new checks and splits through shrinkage that would expose untreated wood to decay organisms in service.

Boxes and Crates

Boxes and crates should be made from lumber that has been dried to a moisture content of 12 to 18 percent. This means that wood ordinarily does not

need to be drier than 12 percent, but it should be at 18 percent or less. These moisture requirements can be readily met by air drying. While the importance of dry lumber has been indicated for boxes and crates, it has also been shown that very low moisture content (6 to 8 percent) will result in reduced strength, largely because of the increased splitting that occurs in nailing. The moisture requirements of lumber for pallets are similar to those for boxes and crates.

House Framing Lumber

In house construction, the different parts vary in tolerance with respect to moisture content requirements. Since framing material is less critical than finish material, it may be installed at a somewhat higher moisture content. Properly air-seasoned material would be considered satisfactory for framing.

Lumber for Interior Service

The moisture content of lumber, such as furniture, interior finish, and flooring, to be used in the interior of buildings, is more exacting than that for lumber used out-of-doors, because of the higher character of the service, and because wood used out-of-doors does not reach so low a moisture content. The optimum moisture content requirements for these items vary for different sections of the country, but have been indicated as about 6 percent for the dry Southwestern States, 10-11 percent for the damp Coastal States, and 7-8 percent for other parts of the United States.

Lumber for Exterior Use

Seasoning is required of lumber for exterior uses, such as siding and trim, to decrease shrinkage and improve conditions for painting or finishing. The approximate optimum moisture content for exterior siding and trim is 9 percent for the dry Southwestern States, and 12 percent for other sections of the country.

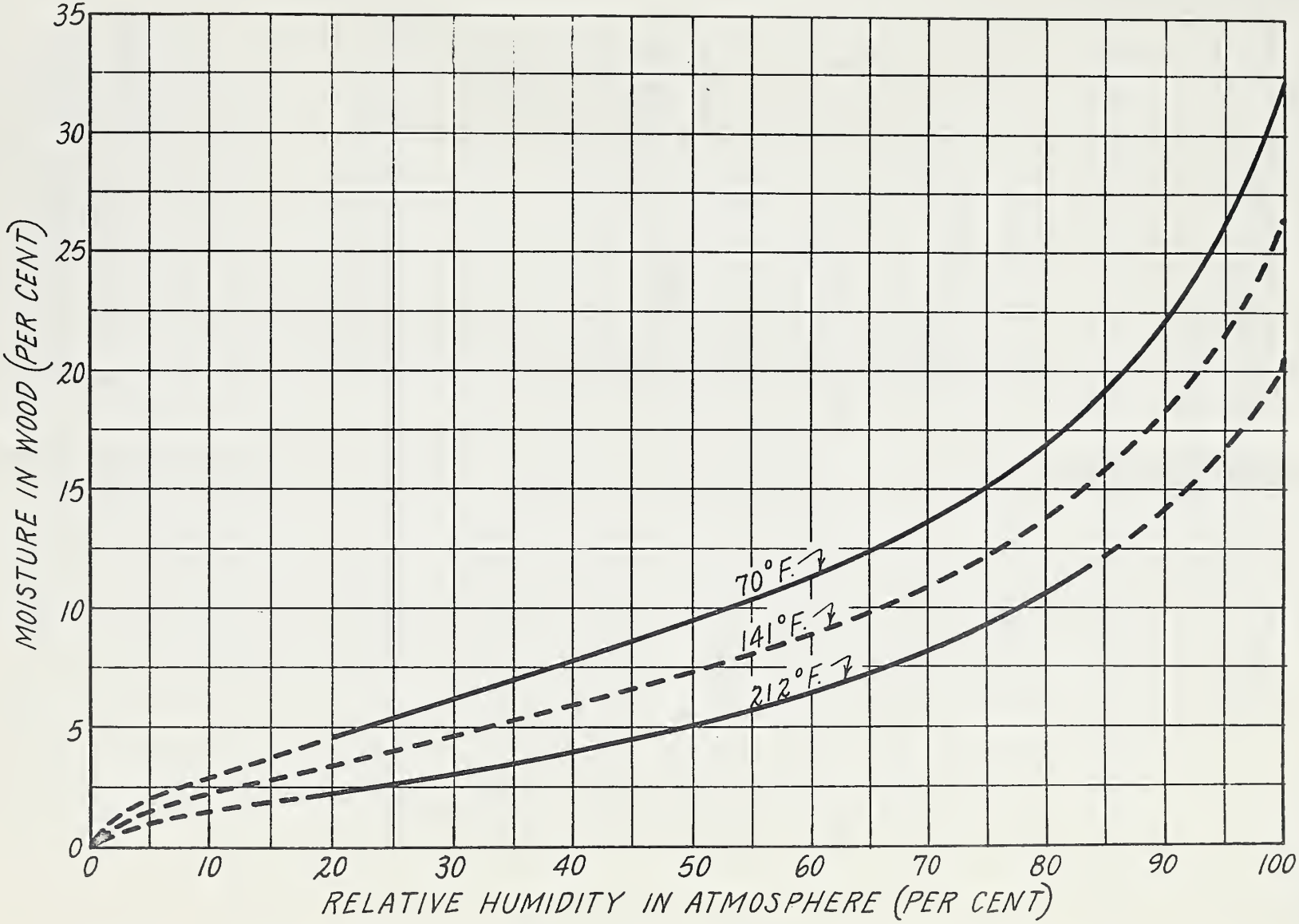

Figure 1. --Relation of the equilibrium moisture content of wood to the relative humidity of the surrounding atmosphere at three temperatures.

SUBJECT LISTS OF PUBLICATIONS ISSUED BY THE

FOREST PRODUCTS LABORATORY

The following are obtainable free on request from the Director, Forest Products Laboratory, Madison 5, Wisconsin:

List of publications on Box and Crate Construction and Packaging Data

List of publications on Chemistry of Wood and Derived Products

List of publications on Fungus Defects in Forest Products and Decay in Trees

List of publications on Glue, Glued Products, and Veneer

List of publications on Growth, Structure, and Identification of Wood

List of publications on Mechanical Properties and Structural Uses of Wood and Wood Products

Partial list of publications for Architects, Builders, Engineers, and Retail Lumbermen

List of publications on Fire Protection

List of publications on Logging, Milling, and Utilization of Timber Products

List of publications on Pulp and Paper

List of publications on Seasoning of Wood

List of publications on Structural Sandwich, Plastic Laminates, and Wood-Base Aircraft Components

List of publications on Wood Finishing

List of publications on Wood Preservation

Partial list of publications for Furniture Manufacturers, Woodworkers and Teachers of Woodshop Practice

Note: Since Forest Products Laboratory publications are so varied in subject no single list is issued. Instead a list is made up for each Laboratory division. Twice a year, December 31 and June 30, a list is made up showing new reports for the previous six months. This is the only item sent regularly to the Laboratory's mailing list. Anyone who has asked for and received the proper subject lists and who has had his name placed on the mailing list can keep up to date on Forest Products Laboratory publications. Each subject list carries descriptions of all other subject lists.